The LLNL Portable Tritium Processing System



The system is made up of modular units that provide tritium pumping, analysis, and effluent scrubbing capabilities. The units are sized to pass through a standard-width doorway and have two containment layers for maximum safety.

THE end of the Cold War significantly reduced the need for facilities to handle radioactive materials for the U.S. nuclear weapons program. Many of these facilities were thus slated for decontamination and decommissioning. LLNL was among the institutions affected by these changed circumstances. Weapons program needs and funding were diminishing while costs for modernization as well as for routine operation were rapidly escalating.

In 1991, the Laboratory decided to close its Tritium Facility, a decision requiring inventory removal and decontamination. In the course of decades of Nuclear Weapons Program work, research was conducted on tritium and tritiated materials. Components using tritium were also developed for nuclear testing at the Nevada Test Site. Fusion energy

research, for which tritium is a key fuel, was also a major focus. Over the years, therefore, tritium and contaminated tritium processing systems had accumulated.

While the decision to close the facility was later reconsidered, the facility's new and ongoing activities in tritium and decontamination research and development continued to require decontamination of its laboratories and removal of most remaining tritium inventory. This process required removing the inventory of tritium within the facility and cleaning up any pockets of high-level residual contamination.

The tritium handling systems at the facility needed to be updated and improved to perform the task of decontamination and decommissioning within today's stringent standards of worker and environmental protection. For example, most such systems had only a single barrier between the system's interior and the laboratory work environment. Today's standards also require more stringent controls of tritium release than in the past.

A project group was formed to develop the best approach for removing the tritium inventory and decontaminating the facility. After considering a variety of inventory removal scenarios, the group decided to design and build a new tritium processing system to current, stringent guidelines.

System Capabilities

During the conceptual design phase, the team identified four basic functions that the system must perform to achieve complete inventory removal. It must:

- Evacuate the facility's gas-handling systems, vessels, and plumbing in preparation for disassembly.
- Analyze the composition of the extracted gases.
- Scrub, or remove, tritium from residual gases.
- Transfer tritium from one container to another or to a shipping vessel that can be sent to another Department of Energy facility for tritium recovery.

In order to be used in the confined spaces of the building that housed LLNL's Tritium Facility, the system would have to be portable so that it could be moved from laboratory to laboratory and could fit into, and work effectively in, confined spaces. The system could therefore be no wider than a standard 36-inch-wide laboratory door.

Designing the System

The combined performance and size criteria for the system posed a major design challenge, because a

system using current technology and meeting current standards would ordinarily fill a sizable room. After consultations and reviews with tritium experts at LLNL, Sandia National Laboratory, and EG&G Mound Applied Technologies, LLNL established the basic design for the Portable Tritium Processing System (PTPS). The design uses current, wellproven tritium-processing technology, but with process components miniaturized and packaged to meet the portability and access requirements. For this reason, the system was divided into three separate modules that, when installed together, provide the required processing capabilities: pumping/transfer, analysis of the gas constituents, and removal of tritium. Figure 1 shows a schematic drawing of such a system's functions and components.

An additional design challenge was posed by the requirement that the system modules operate in a variety of circumstances within today's stringent release criteria. The solution was to design the system with two layers of containment. The system's process plumbing (e.g., pumps, tanks, pressure transducers, valves, flow meters, catalytic reactors, and heat exchangers) would be sealed against leaks (see Figure 2a). The plumbing would be further isolated by a secondary containment layer designed to employ the latest technology for building a glovebox (a sealed box with gloves protruding into it for workers to use in handling materials, such as radioactive substances). Built of 3/16-in. stainless steel with Lexan windows and commercially manufactured gloveports (see Figure 2b), the secondary enclosure of each module is also equipped with a tritium detector to monitor for potential leaks in the process plumbing.

Gloveboxes provide their protection not only by virtue of the sealed mechanical barrier of steel, Lexan, and gloveports, but also by

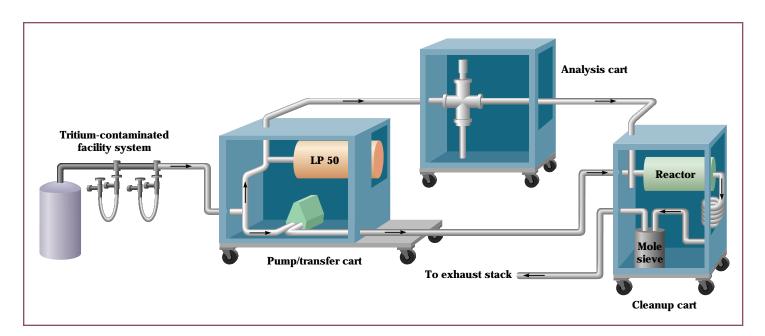


Figure 1. Schematic of the Portable Tritium Processing System (PTPS) showing the three modules and their connecting plumbing.

allowing the atmosphere within the box to be maintained at less than atmospheric pressure. If the box develops a leak, room air will enter the box rather than contaminants leaking out. Indeed, the process plumbing typically operates at vacuum—0.5 Torr (atmospheric pressure at sea level is equivalent to 760 Torr).

Enclosing all process plumbing and hardware in modules presented additional design problems. Several components, such as the catalytic reactor in the scrubber module, generate heat that must be dissipated so that an overpressure (pressure exceeding the set point) does not build up within the enclosures. Such an overpressure could cause a release to the environment and/or damage system instruments. We designed two of the three modules—the analysis and scrubber modules—with ventilation ports that remain open under normal operating conditions. In the event that a tritium detector senses a leak from the process plumbing in these two modules, the ventilation ports close automatically. To prevent an overpressure buildup in the scrubber module when it operates without ventilation, the heat-generating components are insulated so that they release heat at a lower rate than it can be dissipated.

(b)

The secondary enclosure of the pump/transfer module is not ventilated during operation. With a maximum allowable working pressure of only 0.22 psi (pounds per square inch), a leak in the process plumbing during operation could easily create an overpressure. To resolve this potential problem, we added two additional levels of protection against overpressurization of the secondary enclosure. The first is a diverter, or abort, system that uses a series of pressure detectors and valves and an



Figure 2. (a) Part of the primary enclosure system in the pump/transfer module. (b) The steel shell of the pump/transfer secondary enclosure while under construction. Any leak resulting from failure or compromise of the primary system will be contained by this enclosure.



evacuated tank. If excess pressure is detected, the valves divert excess gas to the tank. Although the set point is 0.22 psi, the detectors activate the diverter system at 0.036 psi to give the system time to react. If analysis of the diverted gas determines that tritium is present, the gas can be held in the abort tank for later processing. The second pressure-relief system consists of commercial oil-sealed bubblers. In the extremely unlikely event that the primary abort system fails, the bubblers vent the excess gas to the exhaust stack, protecting the operators from any harmful constituents in the gas.

To prevent oil contamination of recoverable tritium and internal process plumbing, the pump/transfer and scrubber modules use oil-free pumps. The pump/transfer module uses a metal

bellows-type pump in combination with a scroll pump, producing the base pressure of 0.5 Torr. To minimize the possibility of combustion within the pump/transfer module, all electrical spark sources have been located outside the enclosure, including the motors driving the pumps.

The processing system is operated by dual control. A few valves are operated manually, but the rest of the system is operated from a central console, which allows for remote operation of the process modules as space constraints or circumstances require (see Figure 3). The console uses a programmable logic controller to initiate user commands as well as to monitor system status and to automatically activate process-control interlocks that prevent internal pressures, temperatures, and tritium

levels from exceeding the system's handling capacities. If the console fails, the manual secondary control system can bring the system to a safe shutdown condition.

System Operation

A typical decontamination operation requires the use of all three modules—pump/transfer, gas-analysis, and scrubber—in combination with the central control console. The pump-transfer module provides the interface between the system and the manifolds or vessels to be emptied and decontaminated. Because gas pressure within the system to be analyzed is often unknown at the outset, the module inlet manifold has a working pressure of 200 psi (with an internal abort volume to which higher pressure gases would be diverted). As the gas enters the module's process plumbing, a series of electrical pressure transducers measures its pressure at points within the plumbing and relays the readings to the console.

Once the pressure has been determined, a sample is sent at subatmospheric pressure to the gasanalysis module, which houses a commercial quadrupole partialpressure analyzer and pumping station (see Figure 4). The analyzer identifies the gas species present. Using the information relayed from the analyzer to the console, the operator routes the gas to the correct location within the processing system. The decision is based not only on tritium content but on other variables as well, such as the presence of combustible gas mixtures or of materials that would degrade the performance of the scrubber module. If the analysis indicates recoverable quantities of tritium, the gas is routed to bypass the scrubber



Figure 3. The control console gathers data from the modules, including temperature, pressure, gas species, and readings from the tritium monitors; automatic interlocks and shutdown systems operate from the console.

module and is pumped directly into a shipping vessel (see Figure 5) housed within the pump/transfer module (the vessel is a design approved by the Department of Transportation). If the analysis indicates the presence of a combustible mixture, the gas is diluted to a noncombustible state by being mixed with argon gas from the pump/transfer module.

Depending on its tritium content, the diluted gas mixture is either pumped to the shipping vessel in the pump/transfer module for later tritium recovery or is sent to the scrubber module for removal of the tritium. The scrubber removes the tritium by a succession of steps. First, the gas phase undergoes catalytic oxidation, which separates the hydrogen species, including tritium, from the other gas constituents and results in tritiated water (HTO). The tritiated water is collected on molecular sieve drver beds—containers of minerals with spongelike structures. (See Figure 6.) Two molecular sieve dryer beds are configured in series, each with its own downstream moisture monitor. When the monitor for the first bed indicates that the bed has become saturated, the operator stops the process and removes the saturated bed for disposal as low-level waste (less than 1000 curies of tritium). The second bed catches any vapor that passed through the first bed if the process was not stopped in time. The removed bed is replaced by the second bed, which is replaced by a fresh one.

Once the tritium inventory has been removed, the manifold can be further decontaminated in preparation for its removal. (Figure 7 shows a typical manifold.) This step typically involves filling the old manifolds with room air and then flushing the



Figure 4. The gas analysis module. The quadrupole analyzer identifies not only tritium but species of combustible gas.

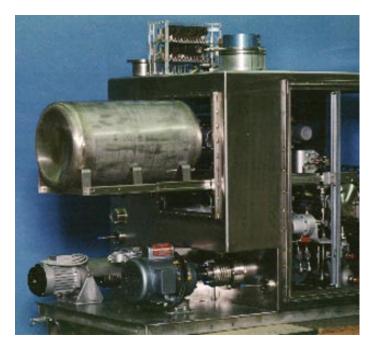


Figure 5. The pump/transfer module with a tritium shipping container resting on its cradle. Once the container has been inserted, the module enclosure is sealed.

air through the scrubber module until the tritium contamination is low enough to allow for safe disassembly. During the flushing, the inlet and outlet tritium monitors gauge the progress of decontamination.

The scrubber module can function on its own for cleaning large enclosures, such as gloveboxes. Additionally, in the event of a tritium leak into the secondary enclosure of the pump/transfer or gas-analysis module, the scrubber module evacuates and scrubs those gases. In the event that the scrubber module itself fails, a duplicate scrubber module can be used to clean up the failed scrubber. Once the failed scrubber is operating correctly again, normal processing can resume.

Figure 6. The scrubber module's catalytic reactor captures gaseous tritium as tritiated water, which is then collected on molecular sieve beds (lower left).



Tritium Inventory Removal Project

The Portable Tritium Processing System was specifically created to execute the Tritium Inventory Removal Project at the Laboratory. This project was designed to be performed in three phases. We have completed the first phase and are executing the second and third phases concurrently.

Phase 1 was the removal of tritium inventory. We consulted the Laboratory's materials management data base and defined anything containing 100 curies or more of tritium as an inventory item. We determined that there were approximately 14 grams of tritium inventory on hand, stored in several

forms—on metal (uranium or palladium) storage beds, bound up on titanium sponges and molecular sieves from old scrubber systems, in the gas phase in high-pressure vessels and old Department of Transportation shipping vessels, and in low-pressure vessels such as flush tanks, sample vials, etc. There were some 80 such inventory items, most connected to or contained within the old manifolds and systems.

Even after the inventory removal phase was completed, some 600 vessels and pieces of equipment remained to be investigated and processed, including approximately 250 detached vessels, 75 to 80 contaminated vacuum pumps of several types, and a few hundred canisters. A canister is a sealed atmospheric pressure vessel containing any of a variety of items—used molecular sieves, packages of waste, or titanium used in old purification systems.

These objects have been the focus of Phase 2. Because of their diverse characteristics and generally smaller size, most of them are better handled inside a glovebox. We have exploited the flexibility of our portable processing system by connecting it to a large, general-purpose glovebox, thereby giving it all the capabilities of our system: tritium monitoring, overpressure sensing, connection to the portable abort system, etc. (See Figure 8.) The vessel being processed is connected to the pump/transfer module from inside the glovebox, so that were it to vent, the workers would be protected and the gas would be contained in the glovebox for processing by the scrubber module.

Once the processed vessels, pumps, and canisters are packaged for disposal as low-level waste and have been removed, the area is ready for Phase 3, which consists chiefly of disassembling and removing old manifolds and

gloveboxes. On completion of Phase 3, the Tritium Facility will have been decontaminated to a level consistent with its future mission.

Summary

LLNL has fabricated a portable tritium processing system that is completely self-contained. It is small enough to pass through a standard-width door so that it can be moved from laboratory to laboratory to perform basic tritium-processing operations. These operations include oil-free pumping and gas transfer, gas analysis, and gas-phase tritium



Figure 7. This complex gridlike structure of piping, valves, and gauges is one of the many manifolds in the LLNL Tritium Facility that have been decontaminated and disassembled.

(a)



(b)



Figure 8. (a) For Phase 2 of the Tritium Inventory Removal Project, the PTPS is connected to a general-purpose glovebox where smaller tritium-containing vessels and tritiated equipment can be examined and manipulated before analysis and treatment by the system's modules. (b) Vern Switzer works in the glovebox to clean out the final tubes of a disassembled facility prior to gas analysis, transfer, and processing.

scrubbing. The system is made up of three separate modules that are built to present glovebox standards and that perform complementary tasks: pumping gases from storage systems, analyzing them, and directing them for shipping or scrubbing, according to their tritium content. The system is operated from a portable console.

While the portable system continues to be the workhorse of the Tritium Inventory Removal Project, now in its final year, strong demand for tritium services has led to reconsideration of plans to close the LLNL Tritium Facility. Instead, the facility will be reconfigured to provide state-of-the-art tritium and radioactive decontamination research and development, with a tritium inventory capacity up to 5 grams. The PTPS is again playing a key supporting role in this new facility direction, this time providing tritium gas handling and glovebox cleanup capability. The system has proven so successful in this application that construction of a duplicate one is now planned.

Key Words: glovebox technology; Tritium Inventory Removal Project; tritium processing.





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